UV-REFLECTIVE INTERFERENCE LAYER SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

5   The present application is a continuation-in-part of (a) U.S. Patent Application Serial No. 09/514,437, which was filed on February 28, 2000, and (b) International Patent Application PCT/EP00/12878, which was filed December 15, 2000. The present application is also claiming priority of German Patent Application DE 199 62 144.6, filed December 22, 1999.

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BACKGROUND OF THE INVENTION

1. Field of the Invention

15   The invention concerns a UV-reflective interference layer system for transparent substrates with broadband antireflection in the visible wavelength range, a method for coating a substrate with such a layer system, and the use of such coating systems in various fields of application.

2. Description of the Prior Art

20   Currently known glass antireflections for the visible spectral range, such as the MIROGARD or the AMIRAN antireflection of Schott-DESAG AG, Grünenplan, are interference filters of three layers, wherein a layer with an intermediate index of refraction is first deposited, followed by a layer with high index of refraction, usually TiO_2, and then a layer with low index of refraction, usually SiO_2 or MgF_2.

25   As the layer with intermediate index of refraction, for example, a mixture of SiO_2 and TiO_2, but also Al_2O_3 is used. Such three-layer antireflections are deposited, for example, on eyeglass lenses, on monitors, on plate glass, such as display window panels, on treated lenses, etc.

In most instances, these filters have a blue-violet or green residual reflection.

30   When light impinges perpendicularly, the reflection characteristic of glasses

coated on both sides is characterized in that the reflection within the wavelength interval of around 400-700 nm is less than 1%, for example, but outside this range the reflection rises to values of up to around 30% (V or W-shaped characteristic), i.e., far above the 8% of uncoated glass.

5   The drawback to such systems is that, when viewing at an angle that increasingly deviates from the perpendicular, the characteristic shifts to ever shorter wavelengths, so that the long-wave reflection maximum ends up in the visible range, and produces an undesirable red component to the reflected light color.

One goal of the present invention is therefore to find an antireflection whose

10   residual reflection is low in a much broader wavelength range, i.e., in the range from 400 to at least 800 nm with perpendicular incidence of light, and which furthermore also provides broadband antireflection at rather large viewing angles. In many applications, such as display window glazings or glazings for pictures, a neutral-color appearance is in fact desirable, especially for different viewing

15   angles.

Especially for picture glazings, say, in museums, but also in the case of display window glazings, furthermore, it is desirable that an antireflecting glass - if possible, color-neutral - at the same time provides the function of protecting the colors of the picture or the natural or synthetic fibers, as well as the dyestuffs of

20   the window displays, against ultraviolet light.

As is known, the UV component of sunlight or that of lamp light, especially in the case of metal halide or other gas discharge lamps, but also even with halogen bulbs, is sufficient to cause considerable damage over a lengthy period of time, such as discoloration or embrittlement of natural or synthetic fabrics. A UV

25   protection would also be desirable for glazings in office or residential buildings, in order to greatly reduce the fading of wood surfaces, draperies, upholstered furniture, etc., under direct sunlight, and thus enable, for example, an improved passive utilization of solar energy. Present-day thermal protection glasses, which contain a thin silver layer, are not antireflective in the visible range, and

furthermore also do not offer sufficient UV protection, since thin silver layers become transparent in the UV.

In the case of known antireflective soft glass, UV protection is achieved by the use of organic polymers as absorbers of UV light, for example, as compound glass, wherein two glass panes are laminated together with a PVB plastic foil adapted by its index of refraction to the glass, for example, 380 µm in thickness (the glass MIROGARD-PROTECT from Schott-DESAG). Such glasses are [used] under intense lamp light, for example, as front panels for lamps, but they are not temperature-stable and they are also degraded by intensive UV radiation. Also, their three-layer antireflection on one side has the above-mentioned limitations, and furthermore the production of compound glass is costly.

Another possibility is the use of UV-absorbing varnish layers, which are several micrometers thick and are transparent to visible light. Such varnish layers are likewise not stable to UV and temperature, and after being deposited on the glass they must further be made antireflective. Regarding the state of the art, refer also to the following publications:

D1:   H. Schröder, "Oxide Layers Deposited from Organic Solutions", in Physics of Thin Films, Academic Press, New York, London, Vol. 5 (1969), pp. 87-140

D2:   H. Schröder, Optica Acta 9, 249 (1962)

D3:   W. Geffeken, Glastech. Ber. 24, p. 143 (1951)

D4:   H. Dislich, E. Hussmann, Thin Solid films 77 (1981), pp. 129-139

D5:   N. Arfsten, R. Kaufmann, H. Dislich, Patent DE 3300589 C2

D6:   N. Arfsten, B. Lintner, et al., Patent DE 4326947 C1

D7:   A. Pein, European Patent 0 438 646 B1

D8:   I. Brock, G. Frank, B. Vitt, European Patent 0 300 579 A2

D9:   Kienel/Frey (ed.), "Dünnschicht-Technologie [Thin layer technology]",
       VDI-Verlag, Düsseldorf (1987)

D10:   R. A. Häfer, "Oberflächen- und Dünnschicht-Technologie [Surface and
       thin layer technology]", Part I, "Coating of Surfaces", Springer-Verlag
5   (1987)

whose disclosure contents are fully incorporated in the present application.

SUMMARY OF THE INVENTION

The object of the invention is to specify a coating for a transparent substrate,
especially glasses, with which the above-described disadvantages can be
10   overcome.

In particular, one should achieve a UV filtering, on the one hand, without the use
of UV or temperature-unstable polymer foils or varnish, and, on the other hand,
the antireflection of visible light should be much more broadband and color
neutral at the same time.

15   As regards the UV filtering, one should achieve approximately the same
characteristics as for foil or varnish systems.

According to the invention, the object is solved by an interference layer system
that comprises at least four individual layers, wherein the consecutive layers have
different indices of refraction and the individual layers comprise UV and
20   temperature-stable inorganic materials.

Especially preferred is an interference layer system of five layers with the
structure: glass +M1/T1/M2/T2/S, wherein the high-refracting material T has an
index of refraction in the range of 1.9-2.3 at a wavelength of 550 nm, the low-
refracting material S has an index of refraction between 1.38 and 1.50, and the
25   intermediate-refracting material M has an index of refraction in the range of 1.6-
1.8, with layer thicknesses of the individual materials in the ranges of 70 to 100

nm (M1), 30 to 70 nm (T1), 20 to 40 nm (M2), 30 to 50 nm (T2), and 90 to 110 nm (S).

In one embodiment of the invention the highly refractive material is titanium dioxide, the low-refracting material is silicon dioxide, and the intermediate-refracting material is a mixture of these substances.

In an alternative embodiment, instead of titanium dioxide one can also use niobium oxide Nb_2O_5, tantalum oxide Ta_2O_5, cerium oxide CeO_2, hafnium oxide HfO_2, as well as mixtures thereof with titanium dioxide or with each other, as the high-refractive layers; instead of silicon dioxide one can also use magnesium fluoride MgF_2 as the low-refractive layer; and instead of Ti-Si oxide mixtures one can also use aluminum oxide Al_2O_3 or zirconium oxide ZrO_2 as the intermediate-refractive layers.

As the transparent substrate, in a first embodiment, one can use soft glass in the form of float glass, including a low-iron form.

As an alternative to this, one can also use hard glasses as the substrate, especially aluminosilicate and borosilicate hard glasses or quartz glass.

Besides the interference layer system, the invention also provides a method for applying it onto a substrate.

In a first embodiment of the invention, the individual layers are deposited by means of the dip method or the spin method of sol-gel techniques.

As an alternative to this, the layers can be deposited by cathode sputtering (for example), by physical vaporization, or by chemical gas-phase deposition, especially plasma-supported.

Especially preferred, the interference coatings according to the invention are deposited on transparent substrates comprising an infrared-reflecting thermal protection coating, or transparent layers comprising an interference layer system

according to the invention are provided with a thermal protection layer, so that a UV-reflective thermal protection glass is obtained.

Thermal protection glasses are based on the principle of reflection of the infrared heat radiation by a thin, electrically conductive coating that is largely transparent in the visible range. Basically, tin oxide and silver-based layers are considered as heat-reflecting coatings.

Tin oxide can be deposited immediately after the float glass production - and application of a diffusion-inhibiting SiOx preliminary coating - in the cool-down phase at around 600°C by means of a spray process. By doping with fluorine or antimony, surface resistances up to 15 Ohms for a layer thickness of around 300 nm are achieved, so that a more than 80% degree of infrared reflection averaged out over the distribution of 300 K thermal radiation is achieved.

As window glazing, therefore, this glass reflects back the majority of the thermal radiation into the space of a building.

The tin oxide deposited by spray pyrolysis during float glass production of interior double-pane glass, for example, must be protected against cleaning, even though it has good mechanical and chemical stability, since substances get worn down due to the relatively high roughness and hardness applied during cleaning processes, and drying is made difficult.

In the double-pane insulated glass composite with an uncoated flat glass pane, these glasses achieve a heat transfer value - depending on the gas filling and the glass spacing - of up to $k = 1.6$ W/m^{2}K. The drawback is the only moderate visible transmission of 75% of such a double-pane insulated glass for two panes with thickness of 4 mm, which is predominantly attributable to the reflection at the boundary layers. The UV transmission, which should be as low as possible not only when used as glazing for museums or textile shops, but also for residential or office buildings, is 35% in the range of 280 to 380 nm.

Instead of doped tin oxide SnO_2:F,Sb, one can also use the transparent
semiconductor materials zinc oxide ZnO:Al (aluminum-doped) and indium oxide
In_2O_3:Sn (tin-doped, "ITO"). Although ITO has a considerably lower
electrochemical stability than tin oxide and requires further treatments after the
spraying process, zinc oxide cannot be produced with sufficient electrical
conductivity by means of a spray process.

Silver-based heat-reflecting coatings achieve significantly more favorable surface
resistances down to less than 1 Ohm and, thus, infrared emission levels of 9 to
4%, at the limit down to 2%, so that k-values of 1.1 to 1.4 W/m^2K are possible on
the basis of such a coated pane in the double-pane insulated glass compound. The
visible transmission in this case is at most 76% and if the silver layers are thicker
it drops to around 68% for k-values below 1.0 W/m^2K. The UV transmission is
36-19%.

The deposition of silver layers is more favorable in terms of thermal reflection,
but after the glass production it must be conducted by costly vacuum coating
methods, and furthermore additional dielectric layers surrounding the silver layer
on both sides and possibly also metal layers to improve the transmission and the
long-term stability are required.

A further drawback is that the silver layer composite can only be used on the
inside of double-pane insulated glasses, since there is no permanent mechanical or
even chemical stability with respect to cleaning processes.

The visible transmission of heat-reflecting insulated glasses, as described above,
is inadequate both in the case of tin oxide and for silver-based layers. With an
antireflection coating on all four boundary surfaces of a double-pane insulated
glass one can obtain glasses whose visible transmission is boosted to 88%.
However, the UV transmission is still 25%.

By applying an interference layer system according to the invention, one can
obtain thermal protection glasses with low transmission in the UV range and high

transmission in the visible range, so-called UV-reflective thermal protection glasses.

Preferably, a UV-reflective thermal protection glass according to the invention comprises an infrared-reflecting thermal protection plate glass, coated with electrically conductive tin oxide, being provided on both sides with a UV-reflective interference layer system, a single pane that is coated on one side with tin oxide and then provided on both sides with the UV-reflective, broadband antireflecting multilayer coating [has] a (mean) visible transmission of 90% or more, as well as a UV transmission (280-380 nm) of 8% or less, while the thermal radiation properties of the tin oxide remain unchanged.

As an alternative to this, UV-reflective thermal protection glasses can be obtained with silver-based, heat-reflecting "low-e" layers, especially in the form of double-pane insulated glasses. If all the other three glass surfaces except the low-e layer applied to the inside of a glass surface are provided with an interference layer system, the visible transmission increases, for example, from 76% to 85% - for unchanged heat-transfer value k - while the UV transmission is reduced from approximately 30% to around 4%.

If the low-e layer is applied on one side of a plate glass previously made antireflecting on both sides with an interference layer system according to the invention, and combined with a second pane made antireflecting on both sides with an interference layer system as a double-pane insulating glass, the visible transmission is further increased to 87%, while the UV transmission is reduced to 3%.

If the second pane is coated on one side with tin oxide prior to making both sides antireflecting with an interference layer system, the k-value will be reduced by around 0.2 W/m^2K, i.e., from 1.0 to 0.8 W/m^2K, for example.

The visible transmission of a single pane coated with tin oxide on one side and made antireflecting with an interference layer system on both sides, having a thickness of 4 mm, is 10% higher in absolute terms than that of tin oxide thermal

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protection glass not made antireflecting, and 2 to 3% higher than that of uncoated float glass. At the same time, the UV transmission is lowered from approximately 45% to 8% without application of polymer varnish or foil.

If one combines a tin oxide-coated single pane provided with the UV-reflective interference layer system on both sides with an identical second pane, the remaining UV transmission will be lowered to 3%, and only a small residue of long-wave radiation will still be admitted in the wavelength region of 360 to 380 nm.

At the same time, the thermal protection properties are significantly improved by the infrared reflection now at two tin oxide layers, and k-values of around 1.2 W/m^2K are possible, such as are otherwise achieved only with silver-based thermal protection glasses. The application of a double, IR-reflecting tin oxide layer is only possible because, thanks to the efficient broadband antireflection of all four boundary surfaces with an interference layer system according to the invention, the total visible transmission is around 87% for normal iron-containing float glass with two panes of 4 mm thickness each.

If - as has been customary thus far - only one layer of tin oxide is used in a double-pane thermal protection glass, the k-value remains at the minimal 1.6 W/m^2K, associated with a somewhat higher visible transmission of 88% and a UV transmission of 4%.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention shall now be described more closely by means of the figures.

These show:

Figure 1   the degree of reflection plotted against the wavelength as a function of the angle of incidence of the MIROGARD antireflection of SCHOTT-DESAG, Grünenplan, according to the state of the art

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DESCRIPTION OF THE INVENTION

Figure 1 shows the dependence of the degree of reflection R on the angle of
incidence for the MIROGARD antireflection of Schott-DESAG. The

measurements of the degree of reflection were plotted for various angles (12.5 to 50°) of the incident light vs. the normal line to the surface.

Figure 2 shows the degree of reflection R for the three-layer AMIRAN antireflections of Schott-DESAG AG, Grünenplan.

5   The systems according to figures 1 and 2 show a strong dependence of the degree of reflection on the angle of incidence of the light.

Figure 3 shows the transmissibility of various UV filters according to the state of the art on soft glass as a function of wavelength. Normal window glass is practically nontransmissible below 290 nm, because of absorption, so that only an

10   improved blocking in the UV-B region, i.e., to 315 nm, and primarily the blocking at 315 and 380 nm remains as a problem.

A MIROGARD three-layer antireflection without plastic foil already provides a slight improvement in the UV blocking by absorption and reflection as compared to uncoated glass. MIROGARD-Protect compound glass is very effective as a

15   UV-A blocker, as are TrueVue and Sky Glas, but TrueVue is very blue in reflection and significantly yellow in transmission.

Examples 1-3 of a system according to the invention with properties that are improved compared to the prior art shall now be described in detail:

Example 1 (color-neutral filter):

20   A UV filter with combined broadband antireflecting action is produced on both sides of soft glass (d = 3 mm, not iron-poor) by the dip method (sol-gel process), for the purpose of the most color-neutral appearance.

The coatings on both sides each consist of five individual layers and possess the structure: glass + M* + T + M + S. The individual layers are applied identically

25   on both sides in a dipping step.

The layers designated T contain titanium dioxide TiO_2, the cover layer designated S contains silicon dioxide SiO_2, and the M layers are each drawn from mixed S and T solutions.

The float glass substrate is carefully cleaned prior to the coating. The dip solutions are each applied in climate-controlled rooms of 28°C with humidity of 7 to 12 g/m^3, the drawing speeds for the individual layers M*/T/M/T/S being: 495/262/345/206/498 mm/min.

The drawing of each gel layer is followed by a baking in air. The baking temperatures and times are 180°C/20 min. after production of the first, second and third gel layers and 440°C/30 min. after the fourth and fifth layers.

In the case of the T layers, the dip solution (per liter) is composed of:

68 ml of titanium-n-butylate, 918 ml of ethanol (abs.), 5 ml of acetylacetone, and 9 ml of ethyl-butyrylacetate.

The dip solution for production of the S layer contains:

125 ml of methyl silicate, 400 ml of ethanol (abs.), 75 ml of $H_2[O]$ (distilled), 7.5 ml of acetic acid, and is diluted with 393 ml of ethanol (abs.) after a resting time of around 12 h.

The coating solutions for production of the oxides with intermediate index of refraction are prepared by mixing the S and T solutions. The layer designated M in Example 1 is drawn from a dip solution with a silicon dioxide content of 5.5 g/l and a titanium dioxide content of 2.8 g/l; the corresponding oxide contents of the M* dip solution are 11.0 g/l and 8.5 g/l.

The wet chemistry sol-gel process used in Example 1, in the form of a dip process, enables the economical coating of large surfaces such as architectural glass with interference filters, wherein the possibility of coating both sides in a single work step and the production of mixed oxides with the particular desired index of refraction are of great advantage.

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Panes can be coated either on both sides or, after covering one side of the glass, just on one side.

Alternative coating methods are physical vaporization in high vacuum and modifications of this process in terms of ionic and plasma assistance, and cathode sputtering.

Figure 4 shows the transmission spectrum of a filter according to the invention in the wavelength range of 280 to 480 nm, made according to Example of embodiment 1 (color-neutral filter). Even without the use of polymer substances, the dangerous UV-B region is completely blocked, and the UV-A region is more than 2/3 blocked, while only the less dangerous range of 340-380 nm is around 1/3 transmitted. It should be noted that the harmfulness of UV radiation increases steadily toward shorter wavelengths.

The transmissibility in the wavelength range of 300 to 380 nm is 15%, which is a UV attenuation by a factor of 4 as compared to an uncoated glass pane (around 60%). In the case of building glazings, however, double panes are usually employed, and less often triple panes. The use of multiple panes further improves the UV protection considerably, as figure 5 shows.

In the case of double panes, each provided with the UV filter according to the invention on both sides, the transmissibility in the range of 300-380 nm is already reduced to 7%; for triple panes, a value of 4% has been measured. At the same time, the reflection losses in the region of visible sunlight for these architectural glazings are only around 1% for single panes, and around 2% or 3% for double or triple panes, respectively. As compared to uncoated glasses, this signifies a 7% reduction of the reflection losses in absolute terms for the single pane, and 14% and 21% for the double and triple panes, respectively.

Especially for glazings of museums and textile specialty shops, this creates a new state of the art, since the five-layer filter of the invention represents only a relatively small additional expense compared to the three-layer solution.

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Furthermore, the filter according to the invention also solves the problem of realizing at the same time a color-neutral antireflection, which also guarantees a color-neutral antireflection at rather large viewing angles, thanks to the broad width of the range of low reflection.

5   Figure 6 shows the measured reflection characteristic of the filter according to the invention in the visible region of 380 to 780 nm as a function of the viewing angle (12.5-50°). A comparison with figures 1 and 2 demonstrates the superiority of the solution according to the invention as compared to MIROGARD and also AMIRAN in terms of broadbandedness, including in particular rather large

10   viewing angles. This is also apparent from figure 7 by comparing the filter according to the invention with these three-layer solutions for a given viewing angle of 30°.

Figures 8a and 8b show the reflection spectrum for a viewing angle of 8° with different scales for R, and a wavelength range that is especially enlarged in the

15   UV direction: the average degree of reflection in the region of 400 to 800 nm is 1%, the subjective color impression is essentially more neutral, especially for large viewing angles above 30°, than is the case with all traditional three-layer antireflections.

As figure 8a shows, the blocking action of the UV filter according to the invention

20   is based primarily on reflection, and less on absorption (UV reflector). The thus-produced optical filters not only exhibit the above-described wavelength-dependent transmission and reflection characteristic, but also are distinguished in particular by a high optical quality, they are free of cracks, opacities, and light scattering, and provide a very color-neutral impression in reflection. Yet neither

25   do they have any color-distorting effect in transmission, which is very important for picture glazings, for example.

The following service-life and application tests were carried out with filters produced according to Example 1 with regard to an application in interior rooms:

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-        Boil test (DIN 51 165), water of condensation/constant climate (DIN 50 017), salt spray/mist test (DIN 50 021), Cass test (copper chloride + acetic acid + NaCl)

and with regard to exterior application

5   -   Test for resistance to water of condensation, test for acid resistance, test for wear resistance (each time requirement category A).

The glasses coated according to the invention withstood the tests indicated here and can therefore be used both in interior spaces and in the exterior field, for example, as architectural glazings.

10   The invention shall now be further explained by means of two additional examples of embodiment:

Example 2 (green antireflection):

A UV filter with combined broadband antireflection action on soft glass, for the purpose of a green residual reflection color, is produced analogously to Example

15   1, but the first layer (M*) of Example 1 is now replaced by a layer M# which is drawn from a mixed silicon/titanium solution of modified composition. This solution has a silicon dioxide content of 11.0 g/l and a titanium dioxide content of 5.5 g/l. Due to the relatively low titanium content, the M# layers thus produced have a somewhat lower index of refraction than M*.

20   As the drawing speeds for the individual layers M#/T/M/T/S there are now selected: v = 540/262/345/206/500 mm/min., obtaining an optical filter with a reflection characteristic according to figure 9, which differs essentially from the filter of Example 1 only in the altered residual reflection in the visible range. The other properties of the filter correspond to Example 1.

25   Example 3 (blue-violet antireflection):

A filter according to the invention, but with blue-violet color of the residual reflection, is produced by the method and also with the individual layers of Example 1, but with the following drawing speeds for M*/T/M/T/S: v = 525/247/302/194/470 mm/min. In this way, a filter with a reflection characteristic according to figure 10 is obtained. The other properties of the filter except for the altered color impression of the residual reflection correspond to those of Examples of embodiment 1 and 2.

The invention for the first time specifies a coating which makes the glass/air interfaces antireflecting in the visible wavelength range (380-780 nm), preferably neutral in color, and at the same time it substantially improves the UV protection properties of transparent substrates in the wavelength range of UV-A (315-380 nm) and UV-B (280-315 nm).

Fields of application of the optical filters according to the invention, besides the coating of glass panes, are the coating of light bulbs in the light industry in order to improve the emitted visible light with color neutrality, especially including that at rather large emission angles, while at the same time reducing the UV radiation. This applies especially to gas discharge lamps with quartz glass bulbs, such as metal halide bulbs, but also to a lesser extent to halogen lamps with quartz or hard glass bulbs.

Furthermore, tubular casings for lamps can be coated with the filter according to the invention, and the filter can be used on planar front panels of hard and soft glass.

An especially preferred usage of the interference layer systems according to the invention is the coating of thermal protection glasses.

Figures 11a through 11c represent application configurations of UV-reflective thermal protection glasses according to the invention, wherein at least one side of a transparent substrate has been coated with a UV-reflective, interference system of five layers. Other layer structures are also possible, as long as the individual

layers contain the temperature-stable inorganic materials according to the invention.

Figure 11a shows a simple system, a so-called single pane, comprising a substrate 100, on whose side facing the interior of a space 102 has been deposited a thermal
5   protection layer, in the present case, a tin oxide layer 104. On the outer side, the single pane comprises an interference layer system 106 according to the invention. With such a system, a transmission of more than 93% and a reflection of 2% in the visible range are achieved, and in the UV range the transmission is reduced to less than 8% of the incident light.

10   The achievable k-value is 3.5 W/m^{2}K.

By using two transparent substrates 100.1, 100.2, it is possible to construct a double insulated glass pane, as shown in figure 11b. In the case of the double insulated glass pane shown in figure 11b, only one transparent substrate, the transparent substrate 100.1, is coated with a heat-reflecting tin oxide layer 104.
15   The tin oxide layer 104 adjoins the interior 108 of the double pane. On all four sides of the two transparent substrates 100.1, 100.2, UV-reflective interference layer systems 106.1, 106.2, 106.3, 106.4 are deposited. With such a system, a transmission of more than 88% can be achieved with a reflection of less than 3% in the visible range. The transmission in the UV range is less than 4%, and the k-
20   value is 1.6 W/m^{2}K.

Figure 11c, in turn, shows a system with two transparent substrates 100.1, 100.2. The system is distinguished from the system of figure 11b in that heat-reflecting layers 104.1, 104.2 are deposited on both transparent substrates 100.1, 100.2 on the inside 108 of the double insulated glass pane. As with the embodiment
25   according to figure 11b, all sides of the transparent substrates are coated with a 5-layer interference system according to the invention.

In a system according to figure 11c, a transmission of more than 87% and a reflection of less than 3% in the visible range are achieved. The transmission in the UV range is less than 3% and the k-value is 1.2 W/m^{2}K.

By UV region is meant primarily the wavelength region of 280 to 380 nm. The transparent substrate used is a non-iron-poor float glass substrate of 4 mm thickness.

In the case of the interference layer systems which are deposited on the thermal protection glass for broadband antireflection, the uppermost of the five layers (S) next to the air has an index of refraction which is less than that of glass (n = 1.52). The layer consists preferably almost entirely of quartz glass (SiO_2, n = 1.40-1.46). The second and fourth layers (T) - viewing from S - consist of a material with a high index of refraction (n = 2.0-2.3), preferably titanium dioxide (TiO_2). The M layers have an intermediate index of refraction of n = 1.6-1.8, which can be realized preferably by a mixed silicon/titanium oxide.

The layer thickness of the M layer(s) next to the glass or tin oxide is 70-100 nm, depending on the configuration of the optical filter, that of the other M layers is 20 to 40 nm, the T layer closer to the glass has a layer thickness of 30 to 70 nm, the T layer closer to S is 30 to 50 nm, and the cover layer (S) is 90 to 110 nm.

These materials are deposited on the glass substrate preferably by dip methods, for example, it is possible to coat a flat glass pane either on both sides or, after covering one side of the glass, just on one side. The thermal protection glasses obtained with the interference layer system according to the invention shall now be explained more closely by means of examples of embodiment:

Example 4:

A plate glass coated on one side with tin oxide (d = 3 mm, not iron-poor, surface resistance 15 Ohms) is provided on both sides identically with a UV-reflective 5-layer broadband antireflection coating by means of the dip method (sol-gel process) in keeping with Example 1 mentioned above, so that a structure STMTM/glass/tin oxide/MTMTS is formed.

The plate glass thus improved has a wavelength-dependent transmission according to figures 12a-12c and a reflection characteristic (when the tin oxide side is

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illuminated) according to figures 12d and 12e. The coatings have a high optical quality and are free of cracks, visible opacities, and light scattering.

One particular feature of the invention is the smoothing out of the tin oxide surface, which is relatively rough prior to the coating, thanks to the 5-layer

5   antireflection coating: while the uncoated tin oxide surface is characterized by roughness values of R_a / R_z / R_{max} = 0.02 / 0.30 / 0.52 µm, these values are reduced to 0.02/0.08/0.10, by the antireflection coating, which corresponds to the values for uncoated float glass.

As cleaning tests show, this also makes possible an application of the tin oxide

10   layer to the outside of glazings, and thus in the simplest instance a single-pane thermal protection glazing, as shown in figure 11a. This is of special interest for exhibition halls, for which thus far it was only possible to use single-pane glazings without a heat-reflecting layer. But since the heat-reflection function is impaired by a coating of water, the tin oxide side must be directed toward the interior of the

15   building.

Figure 12c shows that, in the visible range, only a moderate antireflection action of around 1% is achieved with the coated glass 100 according to the invention - as compared to fully uncoated float glass 102 - but the heat transfer coefficient is lowered from 5.8 W/m^2K to around 3.5 W/m^2K, and thus approaches the k-value

20   of an uncoated insulated glass double pane of around 3.0 W/m^2K. The UV transmission (figure 12b) is lowered from 55% for uncoated float glass 102 or 40% for float glass with AMIRAN antireflection on both sides, to 8% (not shown in figure 12b).

As figure 12a shows, above a wavelength of around 2500 nm in the infrared the

25   optical properties of the tin oxide layer are not altered by the UV-reflective antireflection layers. In the intermediate range of the near infrared (NIR, 780-2500 nm), a considerable sun protection action is achieved as compared to uncoated K-glass 104, since the lowering of the transmission in the range of 1050

to 2400 nm significantly outweighs the transmission gain in the range of 780-100 nm, both times weighted with the incoming radiation spectrum of the sun.

The single pane coated with an interference layer system according to the invention according to Example 4 can also be used to construct double-panel

5   insulated glass.

The single pane according to Example 4, furthermore, can be used as an electric heating panel, if the tin oxide layer is grounded as an antielectrostatic element, or for reflection of electromagnetic waves.

The following service-life and application tests according to DIN EN 1096-2 have

10   been carried out on the filter prepared according to Example 1: testing for resistance to water of condensation, testing for acid resistance, testing for salt spray/mist (neutral), testing for wear resistance, each time requirement category A, and the requirement for architectural glazings has been fulfilled.

Figures 12d-e show the reflection curves for thermal protection glass 104 as

15   compared to thermal protection glass 104 coated with the interference layer system according to the invention.

Additional examples of embodiment for UV-reflective thermal protection glass shall be specified below.

Example 5:

20   A plate glass coated on one side with tin oxide according to Example 4 is provided with a modified 5-layer antireflection, thereby forming the structure STMTM/glass/tin oxide/TMTS, which is equivalent to omitting the thick M layer on the tin oxide side. This is achieved by first gluing together two plate glasses at the edges by the tin oxide sides, then coating the combination with an M layer

25   according to Example 4 by the dip method, separating the panes, and then further coating each of them on both sides with the structure TMTS, all of this according to Example 4.

20

The UV-reflective thermal protection glass according to Example 5 according to the invention has largely the same properties as that produced by Example 4; the major difference is an improved transmission in the visible range of 92%, which is accomplished by a mean visible reflection improved to 1.9%.

5   Example 6:

The method is the same as in Example 5, except that the drawing speed to produce the T-layer closer to the glass is reduced from 262 mm/min. to 220 mm/min., and thus the thickness of this layer is reduced by around 11%. In this way, the mean visible residual reflection is further reduced to 1.5%, so that the visible

10   transmission is further improved to 93%, while the other properties are unchanged in comparison to Examples 4 and 5.

As is apparent, for example from figures 6, 7, 8b, 9 and 10 as well as figures 12b-e, the reflectivity of the interference layer system in the wavelength range of 300-380 nm is ≥ 20% and the reflectivity in the wavelength range of 450-800 nm is ≤

15   5%.

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